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Wasserstein-Distance-Based Temporal Clustering for Capacity-Expansion Planning in Power Systems

Lucas Condeixa
Fabricio Oliveira
Afzal Siddiqui

Aalto University

Γ-opt
Group of Applied Mathematical Modelling And Optimisation

Brief look into the problem and the state-of-art

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- Tejada-Arango et al., 2018: Enhanced representative periods

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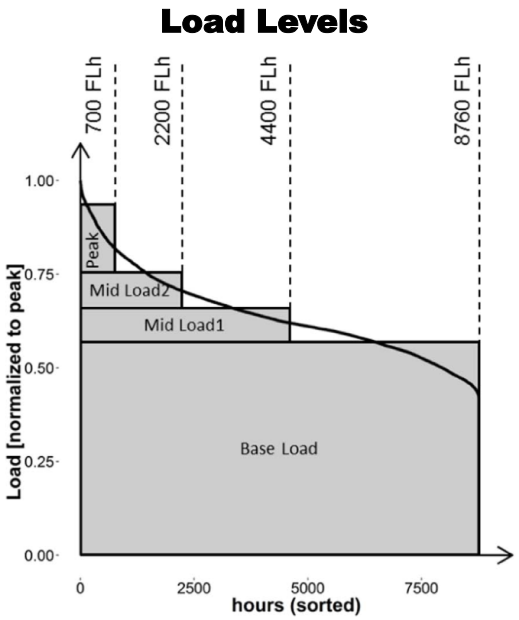
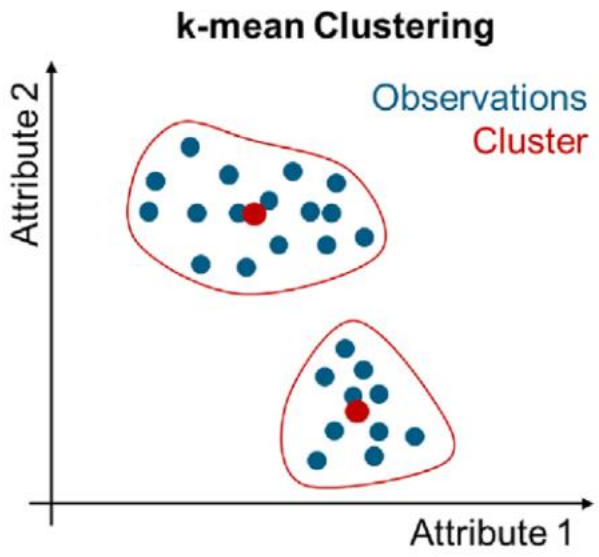
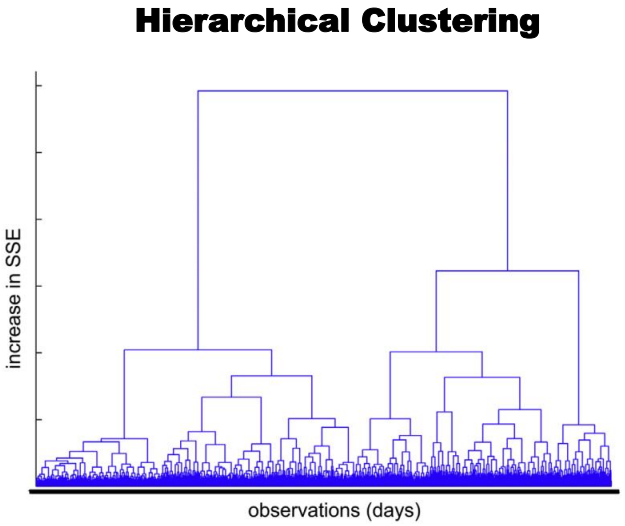


(+) Quick economical indication
(-) Lack the detailing needed for VRES
(-) Poor at estimating operational outcomes (e.g. electricity prices, start-ups and shut-downs, etc.)



(+) Better overall costs estimation than load levels
(+) Possible to elect the most critical features of a system
(-) Restricted at chronological decisions
(-) Randomness of the path (always dependent on the first centroids sorted)



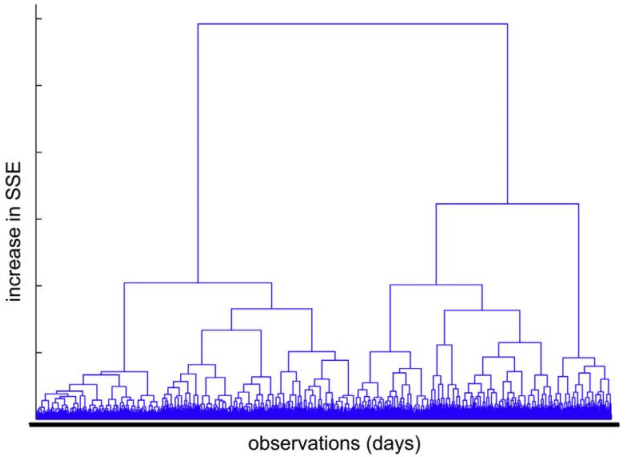
(+) Chronological decisions covered
(+) Consistent path (does not depend on any random classification step)
(-) Weak representation of seasonal patterns

Source: Wogrin et al., 2014; Namacher et al., 2016; Collins et al., 2017; Liu et al., 2018; and Kotzur et al., 2018

Brief look into the problem and the state-of-art

- Chronological decisions will be important to the case studied (i.e. for **storage decisions**)
- We analyze how the choice on the cluster discrepancy measure can improve the Hierarchical Clustering weakness on estimating seasonal patterns

Hierarchical Clustering



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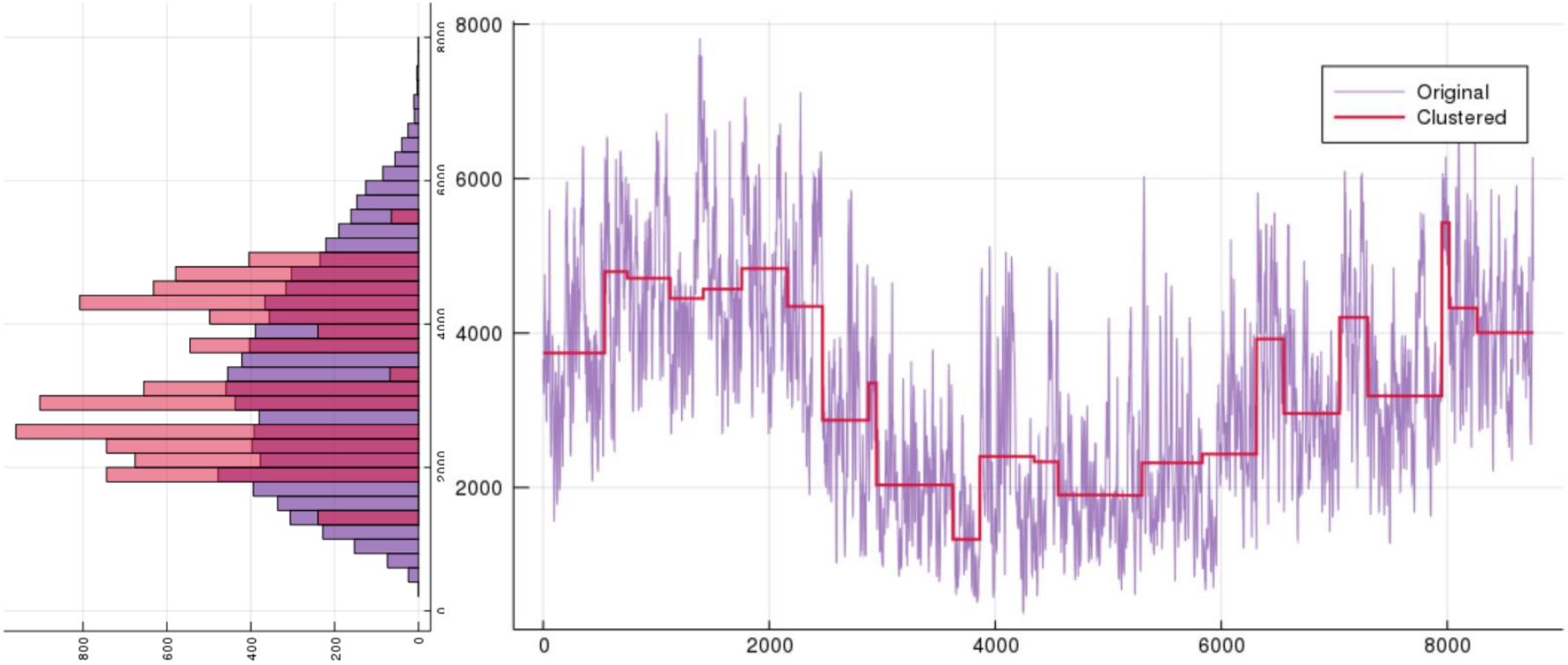
Our proposal and why

- The discrepancy metric used to classify different clusters can play a role in the final decision
- Typically, the Euclidean distance (ED) is used to measure distances between clusters
- If we think about the temporal reduction to be performed in the clustering, the idea is similar to what has been done in scenario reduction techniques used in stochastic optimization => **Wasserstein Distance**

Our proposal and why



$$d^{WD}(Or, Clus) = inf_q \sum_{i,j} q_{ij} \rho(\theta_i, \theta_j)$$

θ_i: Original distribution function
θ_j: Clustered distribution function
ρ : $|i - j|$
q: Quantity transported between i and j

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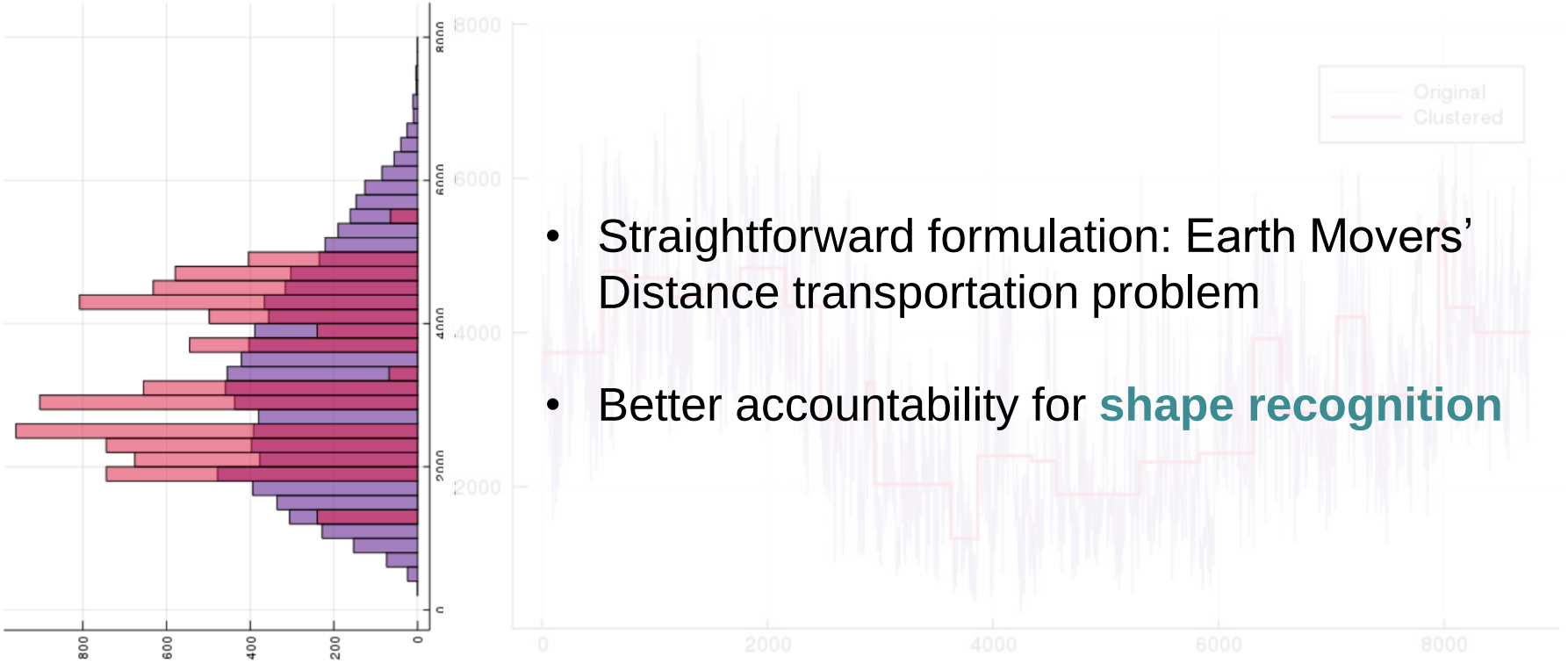

- Straightforward formulation: Earth Movers' Distance transportation problem
- Better accountability for **shape recognition**

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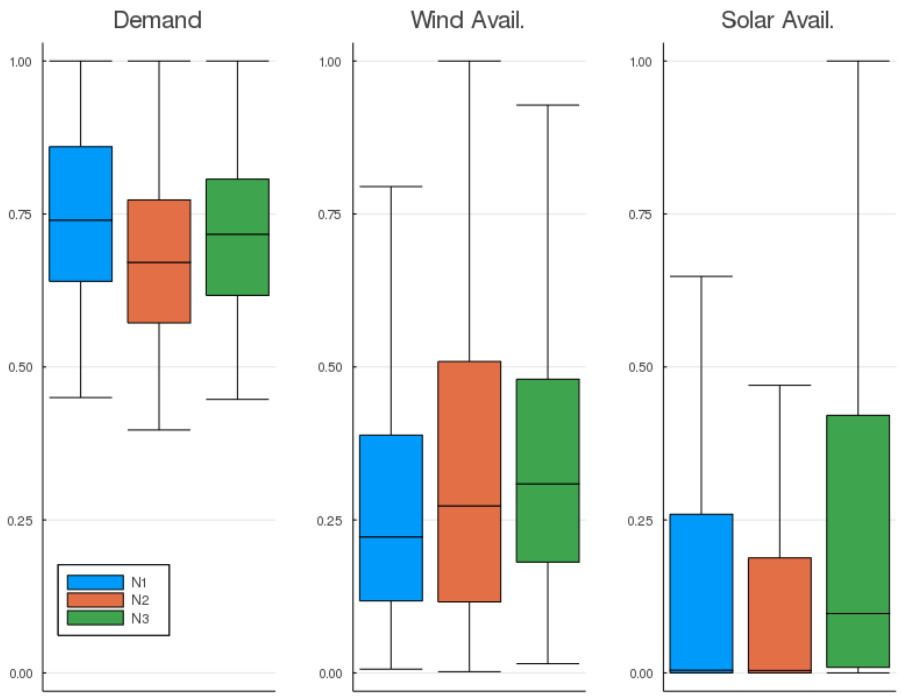
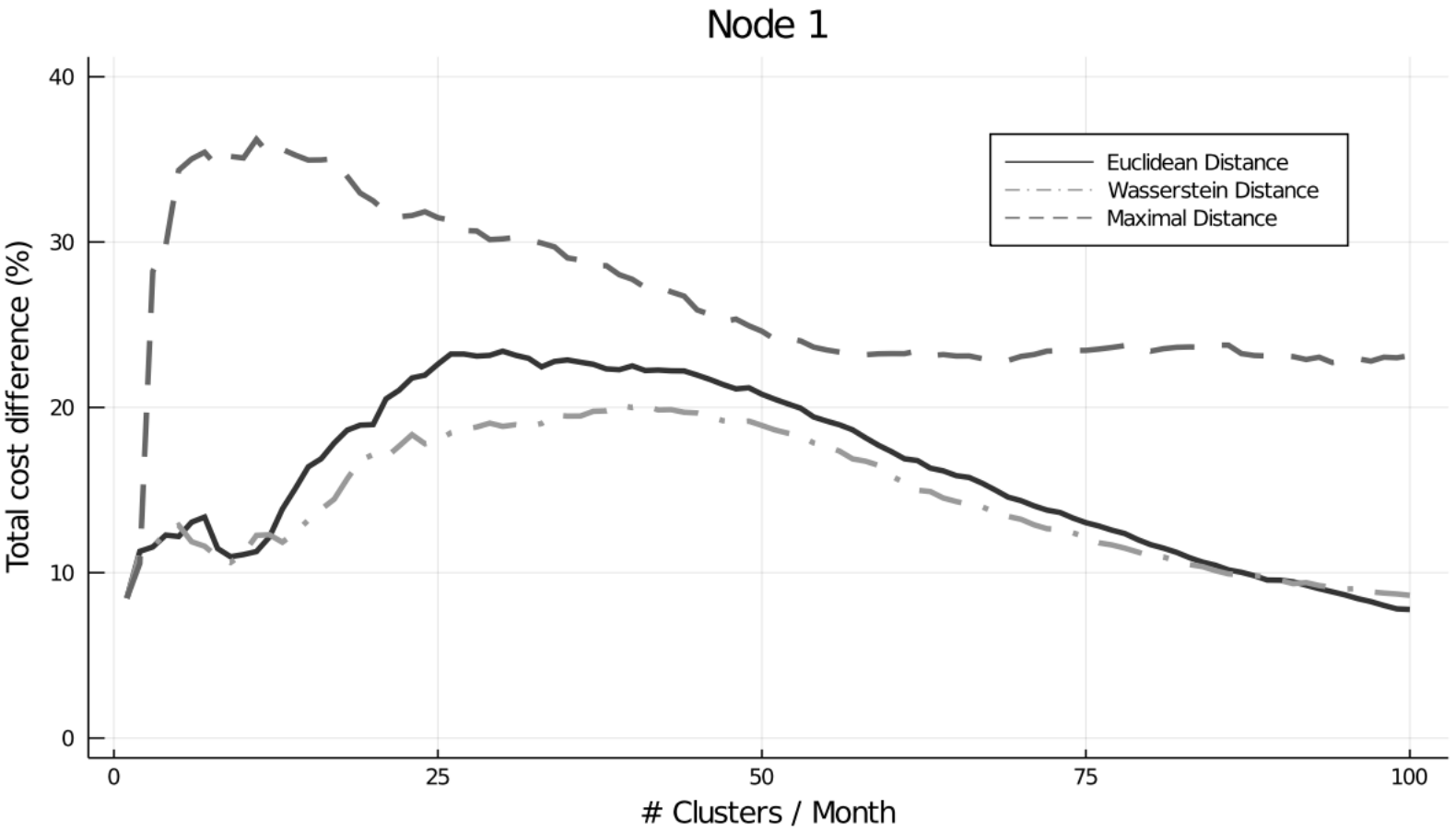
Case study

- Use of three different discrepancy measures (Euclidean Distance, Wasserstein Distance, and Maximal Distance) and comparison of the CEP optimization results
- 3 nodes with different conditions: 1 **high demand** (N1), **windy** (N2), and 1 **sunny** (N3)
- CEP model with battery storage
- 50% minimal renewable generation share
- Perfect competition, i.e., producers have no market power to manipulate prices



Results and Discussion: Cost analysis



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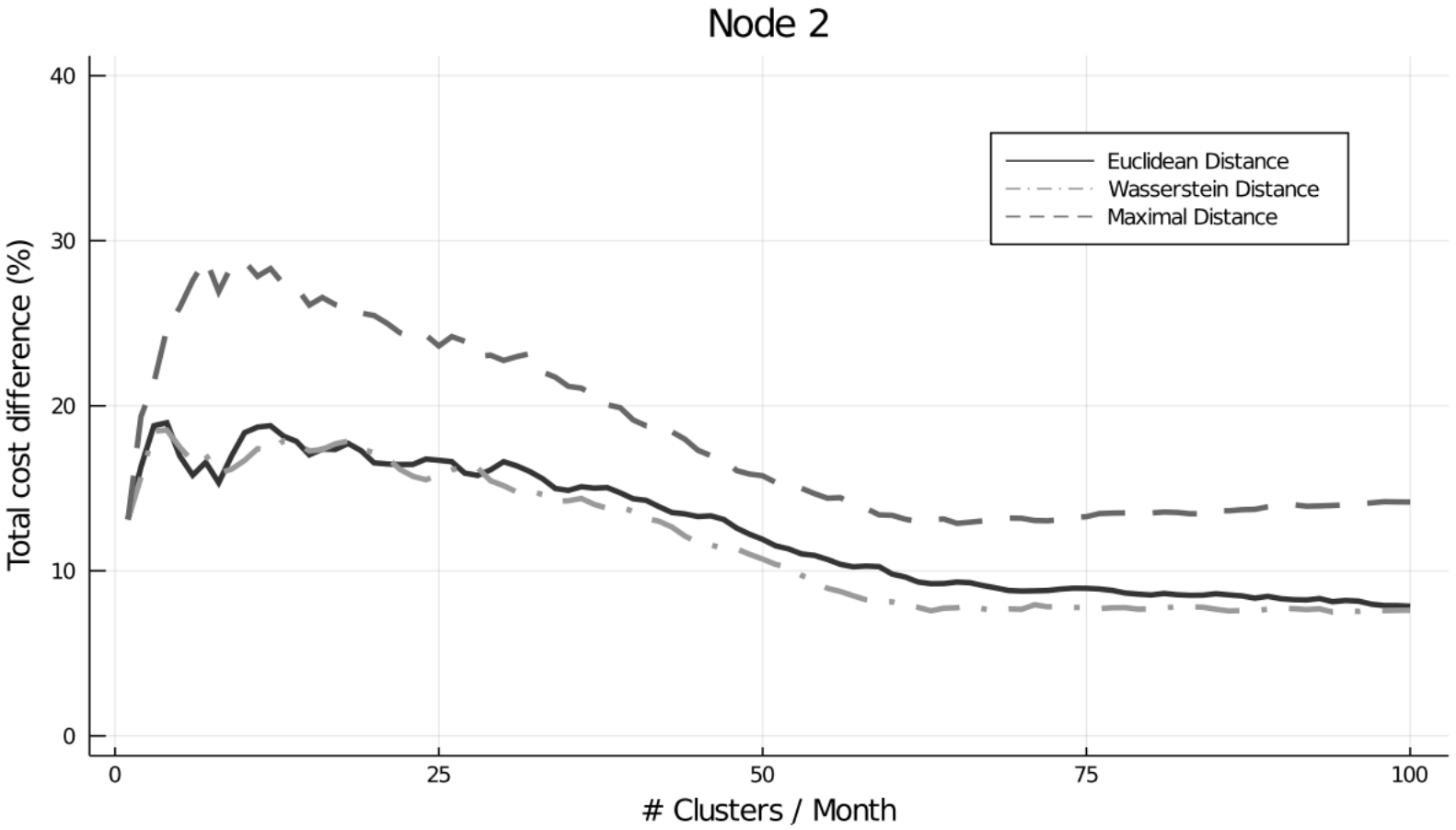

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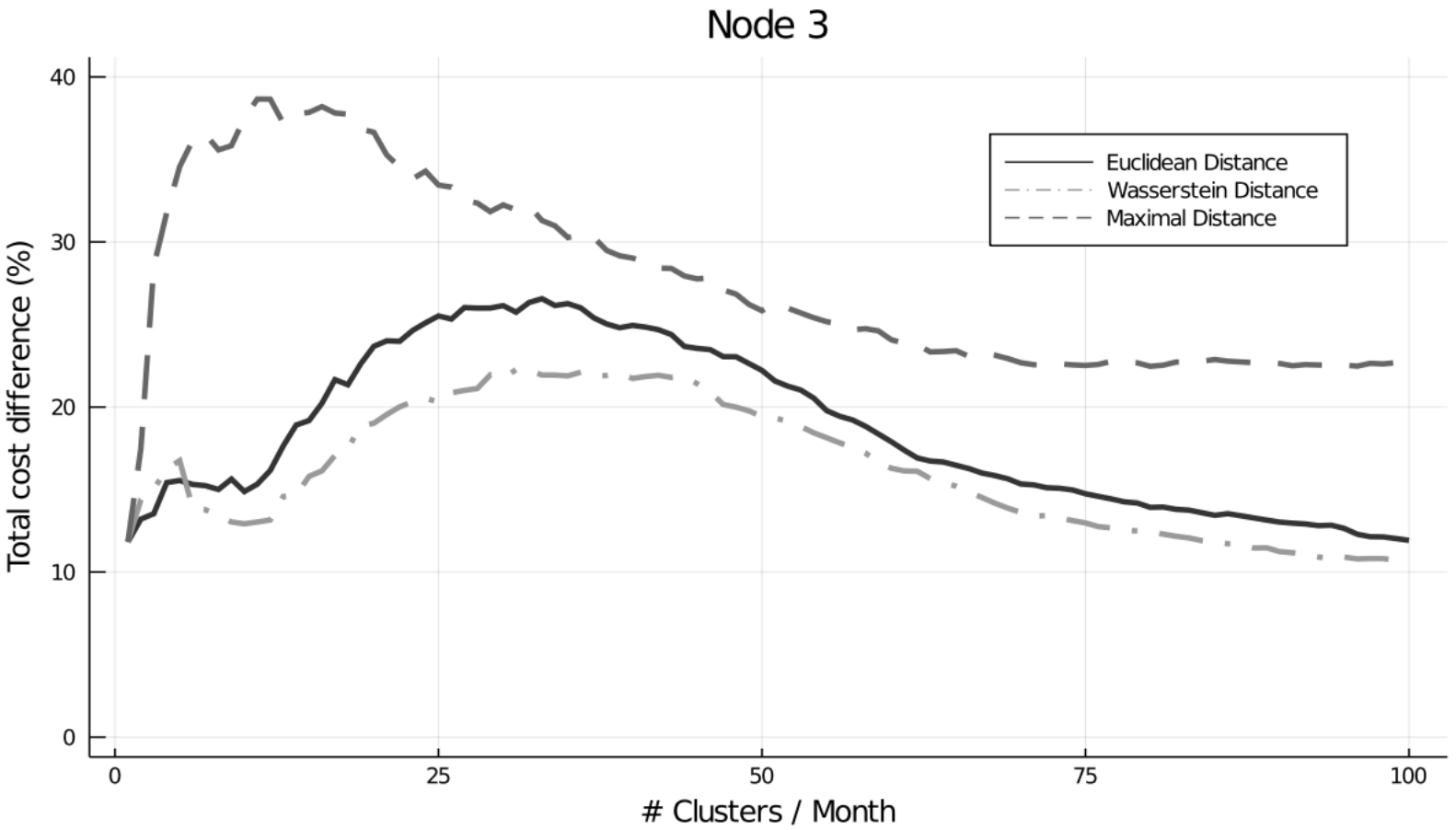
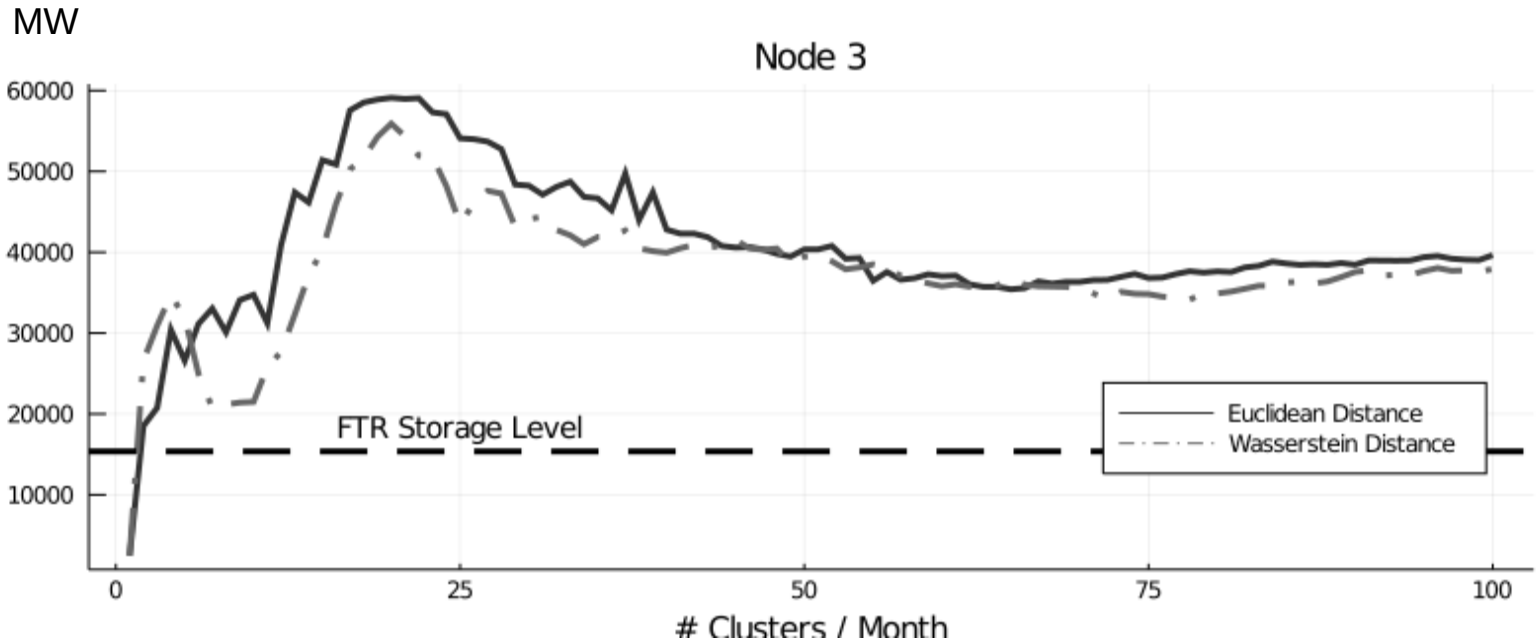
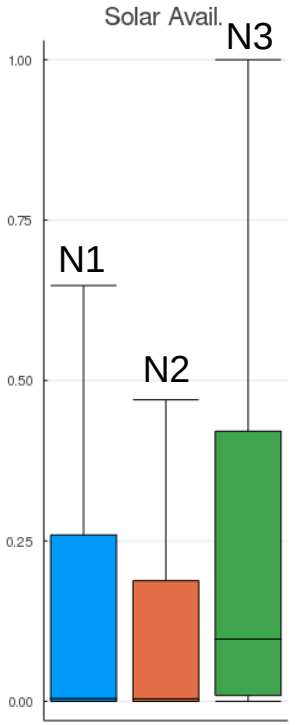


Results and Discussion: Storage capacity (N3)



** Full-Time Resolution*



Solar penetration ↑

Storage Capacity needed ↑

Conclusions

- More **accurate costs** were consistently found for the 3 nodes when using the WD for clustering discrepancy accounting. The estimation of costs is directly related to the cost of capital of an investment. Therefore, by using WD to define clusters, regulators and market players can have a **better estimate on the project's feasibility**

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Future studies

- Despite the good overall costs estimation while using the WD for clustering, the capacity mix did not benefit as much (also it was not the case for the ED or the MD). We recommend a future work focusing on which type of decisions can benefit better of the WD-based clustering and why

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